

# Summary Report

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## *Determination of Evaporation Rate for a Benzene-Containing Solvent Mixture*

EPI Project No. 29125

*Prepared For:*

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EXHIBIT

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## **STUDY OBJECTIVE/PURPOSE**

Many of the products used in residential, commercial, and industrial applications contain mixed hydrocarbon solvents and, historically, these hydrocarbon mixtures could have contained benzene at varying concentrations. The rate at which the benzene evaporates from these mixtures is dependant on several factors including the components of the mixture. Raoult's law applied to ideal solutions is used to estimate the rate at which the benzene evaporates out of mixed hydrocarbon solutions. However, as Elkins and Pagnatto (1963) determined in the 1960s, other hydrocarbons in the mixture positively or negatively affect the evaporation rate of benzene from the solution.

The purpose of this study was to determine the evaporation rate of benzene from a penetrating solvent product manufactured and marketed in the 1960 through 1978 timeframe. The product that was examined was a historic formulation of Liquid Wrench, which consisted of oil dispersed in a solvent based material designed to assist in the removal of rusted and corroded bolts and fittings. In order to determine the evaporation rate of benzene in a Liquid Wrench formulation, benzene in the Liquid Wrench formulation evaporated under controlled conditions while the airborne concentration of benzene was evaluated over time. The concentration of benzene in a specified volume of air per unit time was then converted to mass of benzene per unit of time, thereby determining the mass loss of benzene from the liquid per unit time.

## **METHODOLOGY**

The conservation of mass is a fundamental concept of physics, which means the amount of mass remains constant--mass is neither created nor destroyed. If we change the state of material i.e., in this case a liquid to a vapor/gas phase, the overall mass remains the same but the volume that the fluid occupied changed and correspondingly the density must change also. Since mass remains the same, one can take the product of the density (or airborne concentration) and the volume to determine the mass. Therefore, the mass in the liquid form should equal the mass found in the vapor/gas phase.

This fundamental concept of physics was used in determining the benzene evaporation rate from a historic Liquid Wrench formulation. The Liquid Wrench formulation was allowed to evaporate under controlled conditions in an isolated chamber and air transport system. Air velocity, air temperature, liquid temperature, and humidity were controlled and/or monitored. Scientific principles and standard industrial hygiene and Environmental Protection Agency (EPA) methods, including industry accepted procedures and practices were used for the quantification of benzene in air and conversion to the equivalent benzene mass loss from the liquid medium.

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### *Glove Box-Type Evaporation Chamber (GBTEC) and Air Transport System*

The GBTEC was designed for air to flow laterally through the chamber at a controlled velocity. The inlet ducting measured two feet wide by two feet tall to match up with the GBTEC dimensions. The ducting was made from Dow Super-TUFF-R, a one inch thick polyisocyanurate foam core board with an aluminum foil backing on one side and a plastic backing on the other side. The duct was constructed so that the foil backing made up the interior of the duct. Downstream of the GBTEC, the duct tapered down to a 0.708 feet wide by 0.708 feet tall dimension. Just in front of the taper, a 24 inch square HVAC diffuser was inserted in the reverse direction to collect the air and force it into a 45 degree direction from the incoming air flow and which compressed it through a 12 inch round outlet into the taper. The smaller duct was connected to a 90 degree right turn. The diffuser, taper, and 90 degree turn were designed to promote mixing of the evaporation hydrocarbon solvent on obtain a homogeneity of the mixture in the air stream. The duct continued in a straight line after the 90 degree turn for approximately 14.4 feet.

The GBTEC was constructed of square tubular  $\frac{3}{4}$ " steel frame with Plexiglas sides and sheet steel bottom. The tubular steel was welded together and to the steel plate bottom. The Plexiglas was secured with screws to the tubular steel. Once constructed, the Plexiglas was sealed to the steel using silicone. The removable Plexiglas top section was sealed using soft pliable rubber gasket material. The top section was held in place with bungee cords to allow quick removal and access to the chamber. One side of the GBTEC was fitted with eight inch round ports to allow chemically resistant gloves to be inserted into the chamber.

Prior to initiation of the benzene evaporation rate study, testing of the chamber was conducted in order to determine sampling point locations, confirmation of adequate mixing, and to assure laminar flow throughout the system. Cyclohexane was used to generate a consistent evaporation rate of into the air and measurements were taken with the ChemSense 600 at nine locations in the duct area (the duct cross sectional area was divided up into nine equal sections) and compared these values to determine the standard deviation in values based upon sample location. This result indicated consistent mixing in the air stream. Therefore, the center of the duct was selected as the sampling point for the data collected in the Trial runs.

The GBTEC and duct system were designed to produce laminar flow in the duct work prior to and through the GBTEC so that the air flow could be quantified. A series of holes spaced three inches from the side of the duct and six inches apart were made so that testing of the flow characteristics could be made. Chemical smoke tubes were used to visually document the flow pattern through the GBTEC. The flow was near laminar throughout the GBTEC and met design expectations.

The sampling points for the ChemSense 600 (direct read instrument) and Summa canisters (air grab samples) were located approximately 9.6 feet downstream (approximately 13.5 duct diameters) from the 90 angle. Two viewing windows were inserted to allow positioning of the sampling tubes and for positioning of the thermo-

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anemometer for conducting a secondary thermo-anemometer traverse for flow rate and conversion into volume per unit time. The GBTEC duct system was connected to the air moving device (Abatement Technologies HEPA-AIRE H1000V) and the exhaust from the air moving device was directed to the outside environment.

### *Sampling and Analytical Methodology*

The ICx Analytical Instruments' ChemSense 600 direct sampling mass spectrometer was chosen for this evaluation and positioned to sample downstream from the evaporating benzene or Liquid Wrench mixture. The ChemSense mass spectrometer collected air from the sample stream directly into the vacuum system of the detector where the glow discharge source resides and creates ions inside the cylindrical ion trap mass analyzer (CIT). The ChemSense uses a CIT to separate ions according to their mass-to-charge ratios. Since there is no pre-concentration or distinct sampling event, the resulting data is continuous and, included some averaging, recorded at about 1 Hz.

Summa Canisters were used to obtain air samples of evaporated solvent vapor at the downstream location adjacent to the sampling port used for the direct reading ChemSense 600. A Summa canister is an airtight, stainless-steel container with an inner surface that has been electropolished and chemically deactivated. The advantage of the Summa canister is that the air being sampled is "drawn" into the canister by the high vacuum thereby eliminating the need for pumps or other powered equipment. Two (2) Summa canister samples were obtained for each Trial 1-3 for each day of sampling. The Summa canisters were analyzed in accordance with EPA Method TO-15 by an independent laboratory.

Background/baseline air samples were collected to determine the cleanliness of the air prior to the start and during each trial run. Prior to initiating a trial run, the room air was sampled for two minutes using the ChemSense 600 direct reading instrument. This was then followed by two minutes of air sampled inside the duct while the air moving device was on and set for a laminar flow rate of approximately 25 fpm.

Air samples were also collected at the entrance of the duct system during each trial run using a MSA Escort Elf low volume air sampling pumps drawing air at approximately 0.2 liters per minute through a coconut shell charcoal tube in accordance with NIOSH sampling and analytical method NIOSH 1501. Ambient air samples for determination of background benzene concentration were obtained throughout the duration of each of the 12 trials. These air samples were placed approximately 0.5 m from the upstream duct opening and were analyzed in accordance with NIOSH Method 1501 by an independent laboratory.

Residual oils remaining on the plate glass following the test run were collected and submitted to an independent laboratory for benzene analysis. A razor blade was used to remove any remaining oil from the plate glass and placed into 40 ml bottles with a gas tight silicone/Teflon cap. The sealed bottles were stored under refrigeration at -1.0 °C until shipped under blue ice packs to the independent laboratory.

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The residual oil left on the plate glass after Run 3 was scraped into the bottle eight minutes after the completion of the run. The residual oil left on the plate glass after Run 4 was scraped into the bottle at 29 minutes after the completion of the run. The residual oil left on the plate glass after the run was completed on 15 June 2009 was scraped immediately after the completion of the run.

A VelociCheck thermo-anemometer made by TSI was used to conduct duct traverses at the entrance to the GBTEC to determine the laminar air flow speed and determine the volumetric flow rate based on the size of the duct. The velometer direct reading instrument measures linear air movement across a thermistor sensor detector. Prior to each trial run, the TSI Q-Trak Model 8550 IAQ meter was set on sampling mode and used to data log the air temperature and humidity during each trial over the three day study. The Q-Trak utilizes a thermistor sensor detector to measure temperature with an accuracy of  $\pm 1^\circ\text{F}$ , a resolution of  $0.1^\circ\text{F}$  and range of 32 to  $122^\circ\text{F}$ . Relative humidity was detected with a thin film capacitive sensor, which has an accuracy of  $\pm 3\%$  RH, a resolution of 0.1% and range of 5 to 95%. A Kestrel 4200 barometric pressure meter was set on sampling mode and used to data log the barometric pressure during each trial. The Kestrel contains a monolithic silicon piezoresistive pressure sensor with second-order temperature correction. Accuracy is  $\pm 1.5$  hPa/mb.

A Fluke 62 Mini IR Thermometer was used to measure the temperature of the glass and of the liquid during each trial immediately after dispensing the liquid and at one minute intervals until the completion of the test.

Surface area analysis of the liquid phase was conducted through the use of digital photographic imaging and area was calculated using ArchiCAD software. A template with a grid work of one square centimeter markings was placed beneath the glass surface. Following the pouring of the liquids, digital photographs were taken of the liquid pool at one-minute intervals until the downstream measurement of evaporated solvent was completed. The digital photographs were imported into the ArchiCAD program and the surface edge of the liquid was mapped throughout the evaporation period. Using the template as the calibration guide, the surface of the liquid was calculated in terms of square centimeters ( $\text{cm}^2$ ). Manual adjustments were made on some mapping due to the clipping of a section of the liquid pool.

#### *Historic Formula Recreation*

The Liquid Wrench formulation that was manufactured in the 1960 through 1978 timeframe was selected for use in the benzene evaporation rate study. This product involved a mixture of hydrocarbons identified as "raffinate" and an oil additive. This raffinate material was a by-product of the coal process. According to historical records, this "raffinate" material contained various aliphatic and aromatic hydrocarbons in varying amounts, including benzene at concentrations of approximately 3%.

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The "raffinate" product is no longer available from the coal process. A product manufactured from the oil production process at Sunoco that was determined by analysis to be similar in chemical composition to the original raffinate produced from the coal process back in the 1960s was secured. Three 125 milliliter (ml) containers of this material were obtained for the reformulation of the Liquid Wrench. A base oil was added to the "raffinate" in order to match the original product formulation.

The composition of the reformulated penetrating solvent was analyzed by GC-FID. Analysis was provided by an AIHA, EPA accredited laboratory. Table 1 below shows the concentrations of the individual compounds in the reformulated penetrating solvent compared to the constituents of the historic product formulation. Additionally, the physical properties of the reformulated product were evaluated for flash point, density, and initial boiling point. The American Society of Testing and Materials (ASTM) methods used to determine the physical properties along with the results are summarized in Table 2.

**Table 1: Chemical Composition of Reformulated Penetrating Solvent and Original Product**

Compound	Percent by weight (reformulated)	Avg. Wt. Pct. (original product)
Cyclohexane	17.7	20
m & p Xylenes	14.9	15
Methyl cyclohexane	10.9	12
Toluene	8.7	10
Ethyl benzene	8.4	8
Benzene	5.1	3
n-Hexane	4.0	-
o-Xylene	2.2	2
Pentane	1.5	-
Heptane	0.76	-
Other hydrocarbons	14.1	-

**Table 2: Physical Properties of Reformulated Penetrating Solvent (RPS) and Original Product (OP)**

Parameter	Units	Method	RPS Result	OP Result
Flash point	°F	ASTM D56	87	27
IBP (distillation)	°F	ASTM D86	158.0	170
Specific Gravity	60°/60°F	ASTM D1298	0.7883	0.820

Comparing the chemical and physical properties of the RPS and OP showed generally good agreement. Therefore, it can be concluded that data generated during the benzene evaporation rate study using the RPS is representative of how benzene would have evaporated from the OP.



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## RESULTS

### *Background/Baseline Air Samples Results*

Prior to the start of each trial run, a room-air measurement followed by a duct-air measurement for benzene was conducted using the ChemSense 600. Benzene was not detected by the ChemSense 600 or on any of the charcoal tubes in the room-air at the air duct/chamber intake during any of the subsequent Trials conducted on Day 2 and Day 3. The results of laboratory analysis for ambient benzene sampling are summarized in Table 3.

**Table 3: Results of Laboratory Analysis for Charcoal Tube Air Samples**

Sample No.	Reported Mass (ug)	Reporting Limit (ug)	Volume (liters)	Concentration (ppm)
061109 CHAR-5	ND	1	11.7	<0.027
061109 CHAR-6	ND	1	10.6	<0.030
061109 CHAR-7	ND	1	10.4	<0.030
061109 CHAR-8	ND	1	5.7	<0.055
061209 CHAR-9	ND	1	11.6	<0.027
061209 CHAR-10	ND	1	10.6	<0.030
061209 CHAR-11	ND	1	7.7	<0.041
061209 CHAR-12	ND	1	7.3	<0.043

\*ND = non-detected.

### *ChemSense 600 Results*

A ChemSense 600 ion-trap mass spectrometer recorded the benzene mass concentration during each evaporation trial, which was subsequently converted to the cumulative mass of benzene evaporated per unit time. The half-life (time it takes for one-half of the all the mass of benzene to evaporate from the Liquid Wrench) point of the evaporation period was also calculated.

- For Day 2 (evaporation of 20 ml of reformulated product containing 5.1% w/w benzene from a plate glass) the average benzene evaporation time for Trials 1 through 3 was approximately 12 minutes with an average half-life point of less than three minutes.
- For Day 3 (evaporation of 20 ml of reformulated product containing 5.1% w/w benzene from simulated product use) the average evaporation time for Trials 1 through 3 was approximately 11 minutes with an average half-life point of less than three minutes. Table 4 contains a summary of the evaporation rate data for each trial.

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**Table 4: Time for Half and Time for All of the Initial Mass of Benzene to Evaporate**

Trial Run	Half-life Time (min.)
Day 2, Trial 1 (20 ml LW on plate) ~ 27 fpm	3.05
Day 2, Trial 2 (20 ml LW on plate) ~ 27 fpm	2.76
Day 2, Trial 3 (20 ml LW on plate) ~ 27 fpm	2.67
Day 3, Trial 1 (20 ml LW on part) ~ 27 fpm	2.79
Day 3, Trial 2 (20 ml LW on part) ~ 27 fpm	3.46
Day 3, Trial 3 (20 ml LW on part) ~ 27 fpm	1.76
Day 1, Trial 4 (20 ml benzene) ~ 50 fpm	5.01
Day 2, Trial 4 (20 ml LW on plate) ~ 50 fpm	1.99
Day 3, Trial 4 (20 ml LW on gloves) ~ 27 fpm	1.94

Graphic representations of the cumulative mass evaporation and airborne concentration measured by the ChemSense 600 for each day are shown in Figures 1 through 4 below.

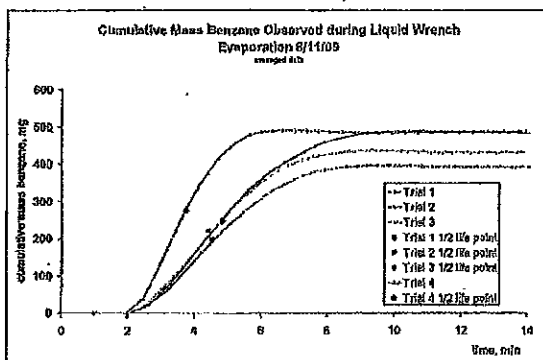


Figure 1

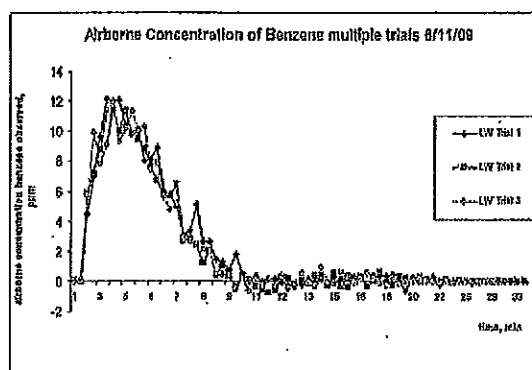


Figure 2

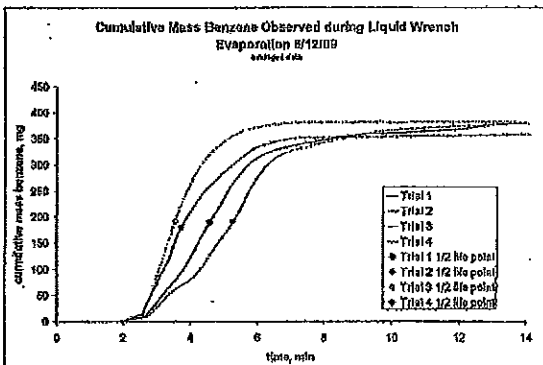


Figure 3

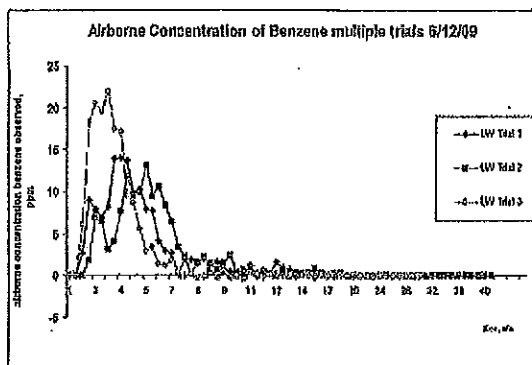


Figure 4



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Figures 1 and 3 show the cumulative amount of mass evaporated from the Liquid Wrench at time =  $t$  in minutes. Figures 2 and 4 show the measured airborne concentration in parts per million (ppm) in the exhaust stream.

### *Summa Canister Results*

Twelve Summa canisters were used to sample the downstream air for benzene that evaporated from the Liquid Wrench. The samples were taken at the same location as the ChemSense 600 for comparison of the data obtained by the ChemSense mass spectrometer. The laboratory reported that canister no.'s 11, and 12 were still under vacuum upon receipt for analysis, and accordingly were not analyzed. Tables 5 and 6 summarize the Summa canister results from days 2 and 3 of the study.

**Table 5: Summa Canister Results for Day 2 – Liquid Wrench Evaporated from Plate Glass**

Can No.	$\Delta t$ (min)	Airborne Concentration in ppm
7	1	9.00
9	3	15.00
11	5	Not Analyzed
8	7	5.00
10	9	0.15
12	11	Not Analyzed

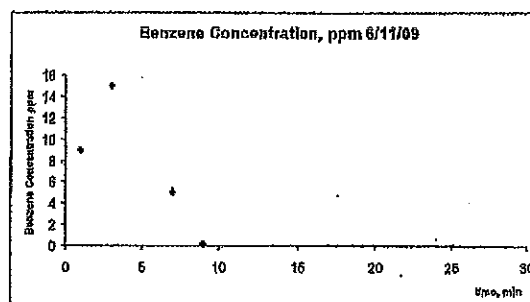


Figure 5

**Table 6: Summa Canister Results for Day 3 – Liquid Wrench Evaporated from Parts**

Can No.	$\Delta t$ (min)	Airborne Concentration in ppm
13	1	11.00
15	3	3.00
17	5	0.62
14	7	1.90
16	9	0.58
18	11	0.04

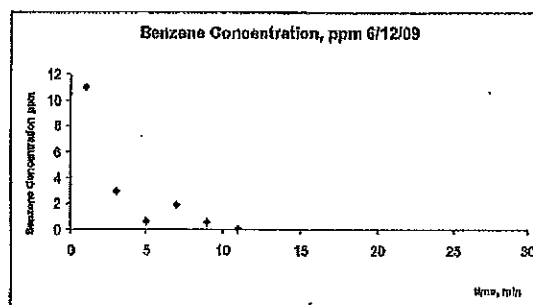


Figure 6

The Summa canister data were the result of very short term grab samples (i.e. 2-7 seconds). Based on the raw data from the ChemSense 600, the fluctuations in the concentration which, when averaged out over time, depict a trend lines as seen in Figures 2 and 4 above that are similar to the trend lines obtained from the Summa canister data, Figures 5 and 6. The Summa canister sample collected at minute 9 of Day 2, Trial 2 showed a concentration of 0.150 ppm. The Summa canister sample collected at minute 11 of Day 3, Trial 3 showed a concentration in the airstream of 0.04 ppm. This

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demonstrates there are extremely low concentrations of benzene left in the Liquid Wrench residue after 9 and 11 minutes of exposure time to the air.

#### *Air Flow Through GBTEC Results*

The average velocity of air through the GBTEC for the three study days was approximately 27.09 fpm for the first three trials. Trial 4 on Day one and Day two were 48.88 fpm and 51.94 fpm respectively. Trial four on Day three was 27 fpm. Table 7 contains a summary of the average velometer results.

**Table 7: Average of Measured Air Velocity in fpm for Each Trial of Study Days 1-3**

	Day 1	Day 2	Day 3	mean
<b>Trial 1</b>	27.63	28.88	26.44	27.65
<b>Trial 2</b>	26.06	25.07	28.69	26.61
<b>Trial 3</b>	27.50	26.34	27.22	27.02
<b>mean</b>	27.06	26.76	27.45	27.09
<b>Trial 4</b>	48.88	51.94	27.00	

#### *Temperature, Relative Humidity, and Barometric Pressure Results*

Over the three days of testing, the average room temperature was 25.5° C and ranged from a low of 24.2° C to a high of 26.2° C. The average temperature of the glass plate inside of the evaporation chamber was 25.4° C and ranged from a low of 23.8° C to a high of 26.4° C. The plate glass temperature tracked closely with the air temperature.

The average relative humidity was 45.7% and ranged from 42.4% to 49.5% over the three day study.

The barometric pressure ranged from 1007.8 millibar (756 mm Hg) to a high of 1013.5 millibar (760.2 mm Hg) over the three days study.

#### *Residual Oil Analysis*

Upon completion of the Liquid Wrench trial runs on Day 2 the remaining oil was scraped off the removed from the plate glass using a razor blade and placed into a 40 ml bottle with a gas tight silicone/Teflon cap. The sealed bottles were stored under refrigeration at -1.0 °C until shipped under blue ice packs to an independent laboratory.

The residual oil left on the plate glass after Run 3 was scraped into the bottle eight minutes after the completion of the run. The residual oil left on the plate glass after Run 4 was scraped into the bottle at 29 minutes after the completion of the run. The residual oil left on the plate glass after the run was completed on 15 June 2009 was scraped immediately following the completion of the run.

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Approximately 2 ml of residue was captured for each run above and sent to the laboratory for analysis of benzene content in the oil. As noted in Table 8, all results were below the limit of analytical detection.

**Table 8: Residual Oil (RPO) From Plate Glass Analyzed for Benzene Content**

Oil Sample Number	Results in ppm and percent by weight
RES-oil-1 (Day 2, Trial 3)	< 25 ppm or < 0.0025%
RES-oil-2 (Day 2, Trial 4)	< 35 ppm or < 0.0035%
RES-oil-3 (Trial 6/15/2009)	< 27 ppm or < 0.0027%

## DISCUSSION

### *ChemSense 600 Confounders and Interferences*

Since the direct inlet mass spectrometric technique on the ChemSense 600 uses no chromatographic separation, all of the chemical compounds present in a mixture are ionized and detected simultaneously. The National Institute of Science and Technology (NIST) standard reference mass spectra for the compounds anticipated to be detected in the gas phase during the evaporation of Liquid Wrench show that there is a slight contribution to the benzene signal from the ethyl benzene and mixed xylenes. When these compounds are ionized, approximately 10% (according to NIST) of the ions produced show up as a benzene signal.

To correct for this interference, a mixture of ethyl benzene and m-xylene was evaporated in the evaporation chamber, and the resulting data allowed for an experimental determination of the fraction of the ethyl benzene and xylene molecules that contributed to the benzene signal. The experimental determination resulted in a ratio that was nearly constant over the entire evaporation episode at 10.38%. The intensity of the signal for the ethyl benzene and xylenes was multiplied by 0.1038, and the result was subtracted from the intensity of the signal for the benzene at the time the ethyl benzene and xylene signals occurred.

During the evaporation of Liquid Wrench, which contained approximately 5% benzene by weight, it was noted that only about one half of the benzene evaporated was observed at the mass spectrometer, based on mass balance calculations that multiplied observed concentrations by measured volumetric flow rate through the evaporation apparatus. The evaporation of pure benzene gave very good mass balance values, so it was hypothesized that one or more compounds in the mixture was suppressing the signal attributed to benzene in the mass spectrometer. Several mixtures of benzene and cyclohexane were evaporated, and the resulting data was used to perform mass balance equations to ascertain if a relationship between the fraction of benzene in a mixture and the fraction of the total mass observed at the mass spectrometer could be obtained. Such a relationship was found to exist and for mixtures with a low concentration of benzene to cyclohexane, signal suppression is occurring. The exact mechanism of this signal suppression was not

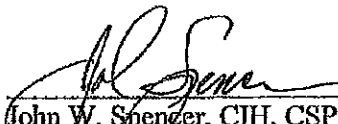
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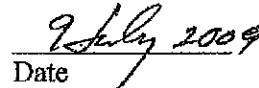
determined, but it should be noted that there is absolutely no evidence to suggest this signal suppression, or "loss of benzene" is anything other than reduced sensitivity of the mass spectrometer for benzene in the presence of the other organic compounds. During the cyclohexane/benzene mixture data collection, all liquid evaporated within the evaporation apparatus, suggesting that all the benzene made it into the vapor phase. However, the concentration of benzene measured vapor phase was suppressed due to the ratio of greater than three (3) to one (1) cyclohexane to benzene in the liquid mixture. The "missing mass," then, is the result of the mass spectrometer, not the result of some physical or chemical process that destroys benzene or keeps it from evaporating.

### CONCLUSIONS

The evaporation of the 20 ml of complex mixed benzene-containing hydrocarbon product (5% wt/wt benzene) at standard temperature and pressure (STP) and with an average airflow rate of 27 fpm at the air-surface interface demonstrated an evaporation half-life on average of less than three minutes.

This study demonstrated a plausible process using mass transfer for determining evaporation rates of single volatile constituent in a complex solvent/product mixture.

  
 John W. Spenger, CIH, CSP  
 Environmental Profiles, Inc.

  
 Date

### Support Documents Follow:

- |                      |                                                                                                                             |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Support Document 1:  | Historic "Raffinate" Formula                                                                                                |
| Support Document 2:  | Bureau Veritas Laboratory Results of Sunoco Raffinate GC-MS                                                                 |
| Support Document 3:  | Bureau Veritas Laboratory Results for Preliminary Liquid Wrench Reformulation GC-MS                                         |
| Support Document 4:  | Bureau Veritas Laboratory Results for Preliminary Liquid Wrench Reformulation GC-FID                                        |
| Support Document 5:  | Bureau Veritas Laboratory Results for Final Liquid Wrench Reformulation GC-FID                                              |
| Support Document 6:  | Historic Liquid Wrench Formulation                                                                                          |
| Support Document 7:  | James Wells deposition excerpts, Historic Liquid Wrench Oil Additive Document                                               |
| Support Document 8:  | Crystal 100 Base Oil Specifications Sheet                                                                                   |
| Support Document 9:  | Penniman & Browne Laboratory Analysis for Physical Properties of Reformulated Liquid Wrench                                 |
| Support Document 10: | Dr. Adam Keil's Benzene Evaporation Study, Direct Sampling Mass Spectrometer Method Development and Data Collection Summary |
| Support Document 11: | Surface Area Data of Benzene Poured on Plate Glass                                                                          |
| Support Document 12: | Surface Area Data of Reformulated Liquid Wrench Poured on Plate Glass                                                       |
| Support Document 13: | Chart Depicting Signal Suppression of ChemSense 600 in Mixtures of Cyclohexane and Benzene                                  |
| Support Document 14: | Field Notes                                                                                                                 |
| Support Document 15: | EMSL Plate Glass Residual Oil Analysis                                                                                      |
| Support Document 16: | MSDSs for Chemicals Used in the Reformulation of Liquid Wrench                                                              |
| Support Document 17: | Study Protocol                                                                                                              |

# **Support Document 1**

## **Historic “Raffinate” Formula**

TABLE I

(ATTACHMENT TO LR-09-A)

## PROPERTIES OF RAFFINATE (D-3)

## Approximate Composition

	Range	Approx. Ave.
Benzene	1-14	3
Toluene	4-40	10
Ethylbenzene	2-16	8
Pure Xylene	1-8	4
Mesa Xylene	3-23	11
Ortho Xylene	1-4	2
Cyclohexane	12-35	20
Methyl Cyclohexane	10-20	12

## Other Components (Partial List)

Pentane	Ethyl Cyclohexane
Cyclopentane	Hexane
Hexane	Decane
Methylcyclopentane	Ethyl Polymers
Heptane	Tri-methyl Benzene
Octane	

## Distillation Range

	Range	Approx. Ave.
Start	74-94 °C	84 °C
50%	95-115 °C	105 °C
Dry	139-167 °C	147 °C

## Specific Gravity

	Range	Approx. Ave.
60/60°	.785-.840	.815

## Flash Points (TCC)

Lo	Hi
< 10° F	+25° F

Reference: Letter from U.S.S. Chemicals, 5/25/77

TR-ja 3-29-78

HB00038

EPI00002